

Women's well-being and household benefits from seaweed farming in Indonesia



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ABSTRACT

Seaweed production in Indonesia almost exclusively comes from community-based farming activities, yet the industry has expanded at an unprecedented rate since 2010 to position the country as the major producer. We explored community perceptions of seaweed farming in South Sulawesi, using a well-being-impact evaluation (W-IE) method. Surveying 74 women from coastal villages where seaweed is a significant source of household income we found evidence of positive economic and social impacts from seaweed farming. Extra income earned from seaweed was instrumental in creation of positive change in 5 out of 10 most important contributors to well-being: transport, housing, basic needs, other needs and education. No negatives changes were linked to seaweed farming and there was evidence of increasing life satisfaction throughout villages, both by women from families who are and who are not engaged in farming, indicating positive equity aspects. This might be due to historical development of the industry in Indonesia, where production is dominated by smallholders. Future interventions that seek to further increase production by focusing on large-scale commercial ventures need to be cognisant of the potential negative economic and social impacts of moving from small-scale to large-scale enterprises, and of the consequent implications for well-being and regional development.

1. Introduction

Farming of seaweed (“aquatic plants”) has grown rapidly throughout the world and is now practised in more than 50 countries (Food and Agriculture Organisation [FAO], 2019). The most prominent market for farmed tropical seaweeds is the industrial use for hydro-colloids (carrageenan and agar), mainly from *Kappaphycus alvarezii* (commonly called ‘cottonii’), *Kappaphycus striatum* (‘sacol’), *Euचेuma denticulatum* (‘spinosum’) and *Gracilaria* species (Valderrama et al., 2013). Starting in the Philippines and then Indonesia, these species have since been introduced to Malaysia, Tanzania (Zanzibar), Brazil, Solomon Islands, Fiji, Kiribati, India and Mexico (FAO, 2016). However, although seaweed aquaculture has developed into a lucrative commercial business and export industry for Indonesia and the Philippines (Hurtado et al., 2015), in other places it is only one of the diversified livelihood sources for marginalized coastal villagers (Mantri Vaibhav et al., 2017; Morris et al., 2014; Msuya and Porter, 2014;

Namudu and Pickering, 2006; Neish, 2013; Nor et al., 2017; Pickering, 2006; Rebours et al., 2014). A clearer understanding of the dynamics in Indonesia could potentially assist other emerging production countries to better harness their opportunities and potentially replicate the growth of seaweed farming in Indonesia. This study contributes to this understanding by evaluating the economic and social benefits that seaweed farming is perceived to bring to coastal villages in southern parts of the Sulawesi Island in Indonesia.

The Indonesian government has in place a policy to increase both the production of seaweed and its further processing, the aim being to ensure that a greater proportion of seaweed is processed domestically, that value-added products are created; and that new species for production are developed (Government of Indonesia, 2015). Statistics suggest that the government policy has been largely successful: the annual farmed seaweed output is reported as having increased by more than 10 times between 2005 and 2014 (FAO, 2016). Seaweed farming in Indonesia comprises three main value chains. The first is mariculture

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(farming in the sea) of the carrageenophytes *Kappaphycus* and *Eu-cheuma* in shallow coastal areas, particularly sheltered bays. Dried *Kappaphycus* and *Eu-cheuma* is sold to middlemen for processing either in Indonesia or offshore (Neish, 2013). The second is pond culture of the agarophyte *Gracilaria*. Most *Gracilaria* culture is undertaken in coastal ponds, where it is commonly polycultured with milkfish *Chanos chanos* or shrimp (Rimmer et al., 2016; Malik et al., 2015). Dried *Gracilaria* is sold for processing to agar (Neish, 2013). Recently, mariculture production in Takalar Regency has diversified to include cultivation of *Gracilaria* using techniques similar to those used for *Kappaphycus* and *Eu-cheuma*. Maricultured *Gracilaria* enters the same value chain as pond-cultured *Gracilaria*, although maricultured *Gracilaria* appears to be supported by a single Indonesian agar processor. A third value chain is local consumption of seaweed and seaweed-based products. This includes the edible seaweed *Caulerpa*, which is cultured in coastal ponds. In South Sulawesi and in some other parts of Indonesia *Caulerpa* is sold directly to local wet markets and used as a salad vegetable (Putra et al., 2013). Local markets also sell dried units of *Kappaphycus* and *Eu-cheuma* as sea vegetables, as well as the seaweed-based products such as cakes, snacks and soap.

Although there are many anecdotes about the social and economic benefits of seaweed farming to small-holders and associated communities, data to support these claims is limited, with counter-claims that seaweed farming is arduous work and may have health ramifications (Fröcklin, 2012). In contrast to many other parts of the world, seaweed farming in Indonesia is almost exclusively undertaken by small-holder farming families (Cai et al., 2013; Neish, 2013). The literature from Indonesia explores both the family farming income and the greater economic benefits of seaweed farming. Estimates of farming income and enterprise budgets have been reported by Neish (2013) and Valderrama et al. (2015). Although it is possible to access data on production volumes and price, from which one can estimate incomes at regional scale, seaweed prices have been particularly volatile over the last 10 years, resulting in a non-linear relationship between farming volume, value and income (KKP, 2014). Data on numbers of households engaged in seaweed farming is unreliable, so a case study approach is needed to calculate average seaweed income per household or a village (Malik et al., 2015; Neish, 2013). Estimating household profit (income minus cost) is even more difficult, since relevant cost data are not available (Cai et al., 2013; Neish, 2013). Even if such data were available, profit estimates alone would not provide a comprehensive view of social and economic benefits of seaweed farming: one needs information on how money is spent. Higher income does not automatically translate into socio-economic benefits and improved well-being (Rojas, 2008), and may, indeed, have a negative overall impact if spent on 'social ills' such as drugs, alcohol, gambling or prostitution. There is a substantial body of literature highlighting the fact that GDP and other income measures are very poor approximations of well-being (see, for example, Kubiszewski et al., 2013; Costanza et al., 2016).

Nonetheless, existing evidence from the major farming region of South Sulawesi indicates that the socio-economic impacts of seaweed farming on coastal communities have been positive (Blankenhorn, 2007; Cai et al., 2013; Neish, 2013; Putra et al., 2013). Seaweed farming is also purported to positively affect the socio-economic status of female farmers, since it allows them to engage in an income-earning activity that can be undertaken without neglecting traditional household chores. However, there is a general lack of understanding of the impact of aquaculture on women, in particular of its broad costs and benefits and the factors shaping these (FAO, 2017).

In this paper, we focus on a significant seaweed producing area in South Sulawesi, the Takalar Regency, as a case study. First, to support our argument and justify the need for alternative approaches to evaluating social and economic impacts of seaweed farming, we collate and present existing and available seaweed farming data for production volumes and revenue from seaweed for the 2013–17 time period. We then report on data collected via interviews with 74 women from

seaweed farming villages in Takalar Regency. First we explore their perceptions of satisfaction with life overall. Second, using a recently developed well-being impact evaluation (W-IE) approach, we unpack the life satisfaction into a range of well-being contributors and establish their importance to respondents, as well as the change in satisfaction with each contributor over 2013–17 time period. We then ask respondents what has caused that change in satisfaction, exploring potential perceived linkages between improved well-being and seaweed farming. Finally, we compare the two possible approaches – use of secondary production data as a proxy and primary data collected from farmers as per W-IE approach – to make a case for a need to improve the triangulation of data collection and to also encourage discussions about what the economic 'benefit' of seaweed farming is for coastal communities.

2. Methods

2.1. Study location

Indonesia's production of seaweed has increased dramatically in recent years, with its share of world farmed seaweed production increasing from 7% in 2005 to 37% in 2017, second only to China (FAO, 2019). Indonesia has been the largest carrageenan seaweed exporting country for most of this decade (Neish, 2013). In recent years, the island of Sulawesi – and in particular South Sulawesi Province – has become the centre of seaweed production (Fig. 1), growing from 26.4% of national production (2.42 million tonnes) in 2013 to 34.7% (3.66 million tonnes) in 2017. Seaweed culture is a major source of income to coastal communities in several regencies of South Sulawesi province, particularly Takalar and Bulukumba regencies. We undertook this study in Takalar Regency, where all three seaweed production value chains were observed and the study respondents were involved in culture related to all three value chains.

2.2. Well-being impact evaluation (W-IE) approach

Methods that allow for investigations of impacts of policy changes or development interventions on peoples livelihoods – beyond mere income estimates – are most notably those emerging from the well-being and life satisfaction literature. These approaches quantify subjective perceptions of well-being and allow one to explore the link between policy changes (for example, growth in seaweed farming) and well-being. They are becoming an increasingly important tool in international development, planning and management (Hassan et al., 2005; Jarvis et al., 2017; Larson, 2010; Li et al., 2019; Stoeckl et al., 2018) primarily because these approaches allow for multi-dimensional explorations of complex changes. Having a better understanding of people's subjective well-being also indicates the most effective means of enhancing it (Marans, 2003). The subjective well-being construct deals with the perceived levels of benefits and satisfaction gained through various factors including economic, health, social, ecological, institutional and cultural factors (Alkire, 2002; Millennium Ecosystem Assessment, 2003; Larson, 2011). The approach takes into account individual experiences and helps to understand and communicate the interpretations, priorities and needs of people (Diener and Suh, 1997; Max-Neef, 1991, 1995). Numerous empirical applications of the approach worldwide have shown that complex and intangible impacts of change which cannot be measured in monetary terms are often just as significant to human well-being as the more tangible, often monetary, impacts; perhaps even more (Soderbaum, 2013).

In this paper we use a recently developed well-being impact evaluation (W-IE) approach to investigate the impacts of seaweed farming, including, but not limited to, financial impacts. The W-IE approach combines insights from the life satisfaction literature, and from literature on the Theory of Change, Impact Evaluation, and Well-being to assess the 'impact' of a change or 'intervention' (Larson et al., 2019a).

Table 1
Well-being factors, abbreviation (text in **bold**), and the corresponding Bahasa Indonesia phrase used in the game

	Well-being factor (abbreviation in bold)	Phrase used on cards
1	Having good quality clinics and hospitals close by (clinics)	Dekat dengan PUSKEMAS/RS
2	Having houses that are in good condition (houses)	Rumah yang bagus
3	Having motorised transport (e.g. motorcycle, car) (transportation)	Punya Motor/Mobil
4	Having good quality schools close by (schools)	Dekat dengan Sekolah
5	Being able to send the children to highest education level (e.g. at least until bachelor degree) (University)	Anak bisa ke Universitas
6	Social networking (SN)	Punya jaringan social (banyak teman)
7	Sharing experiences and learning new skills (learning)	Berbagi pengalaman & belajar keahlian baru
8	Having good role models in the community (role models)	Menjadi panutan di tengah masyarakat
9	Being close to the market (market)	Dekat dengan pasar
10	Being strong and healthy (health)	Sehat fisik dan mental
11	Being able to go for Hajj (Haji)	Bisa berangkat haji
12	Safety: Knowing that the village is a safe place (e.g. not many robberies or violence) (safety)	Desa Aman/Damai
13	Law enforcement: Knowing that people who behave outside the law are punished (law)	Hukum ditegakkan
14	Having jobs that people enjoy doing (not just jobs for money) (job satisfaction)	Pekerjaan yang menyenangkan
15	Having jobs available in the local village (local job)	Tersedia lapangan kerja
16	Having more money to fulfil basic needs (basic needs)	Kebutuhan dasar terpenuhi
17	Having more money for additional things (secondary needs) (other needs)	Punya uang lebih untuk kebutuhan lain
18	Having your own businesses within the village (own business)	Punya bisnis sendiri
19	Having clean and safe drinking water (water)	Akses ke air minum bersih
20	Having a clean and healthy natural environment (e.g. beaches, ocean, rivers, mountains) (environment)	Lingkungan bersih dan sehat
21	Equity within the village (equity)	Setara dengan orang lain (direkeng)

Indonesian Aquaculture Statistics ([Buku Statistik Perikanan Budidaya, 2017](#)) data sets for the years 2013 to 2017.

First, we asked respondents to tell us, on a scale of 0–10, how satisfied they were with life overall – both now, and 5 years previously (when seaweed farming was still in the early stages of development in the area). We used a non-parametric related-samples Wilcoxon signed rank test to compare median differences between satisfaction levels now and 5 years ago; and tested for statistically significant differences in life-satisfaction scores between women from seaweed farming households and those who do not have a seaweed farm, using the Mann-Whitney *U* test, a rank-based non-parametric analysis (IBM SPSS v24). We also collated and graphed secondary data.

For the second part of our explorations, we used the Well-being Impact Evaluation (W-IE) method and the well-being game, collecting data about perceptions of the impact which seaweed farming has had upon various economic, social and environmental factors which respondents felt were most important to their overall well-being. As a first step, we used insights from our experience and the broader literature to compile a list of factors likely to be important to the well-being of respondents ([Larson, 2011](#)). The list was updated during the expert discussions, enumerator training and the pilot, to ensure regional relevance and clarity. The final list comprised 21 well-being factors presented to respondents ([Table 1](#); including their abbreviations, the

Bahasa Indonesia and, where appropriate, local dialect wording used in the game).

Those who agreed to be interviewed were presented with the list of factors and asked to participate in a ‘well-being game’. The game is played in slightly different ways in different contexts (countries). In some cases, for example where the expected literacy of participants is low, the game is played using pictures that represent well-being factors. In other cases, pile-sorting exercises are used. For this particular study, a board with statements about each of the 21 factors was printed and participants were given six tokens which they could place on the board to indicate up to six most important factors to their personal well-being. They were then asked to assign each selected factor a score (from 1 to 10) to indicate how important they are to their well-being. For each of the factors thus selected respondents were also asked to provide satisfaction scores on a scale from 0 to 10 to indicate (a) how satisfied they are with the status of that well-being factor now; and (b) how satisfied they were 5 years ago. Finally, respondents were asked to explain what they thought had happened to cause the perceived changes in satisfaction (positive or negative). The objective of the game was to capture perceptions of the things most important to respondents’ overall well-being, and of perceptions about what caused changes to those important things, without ever ‘leading the witness’ by mention of or asking questions about seaweed farming.

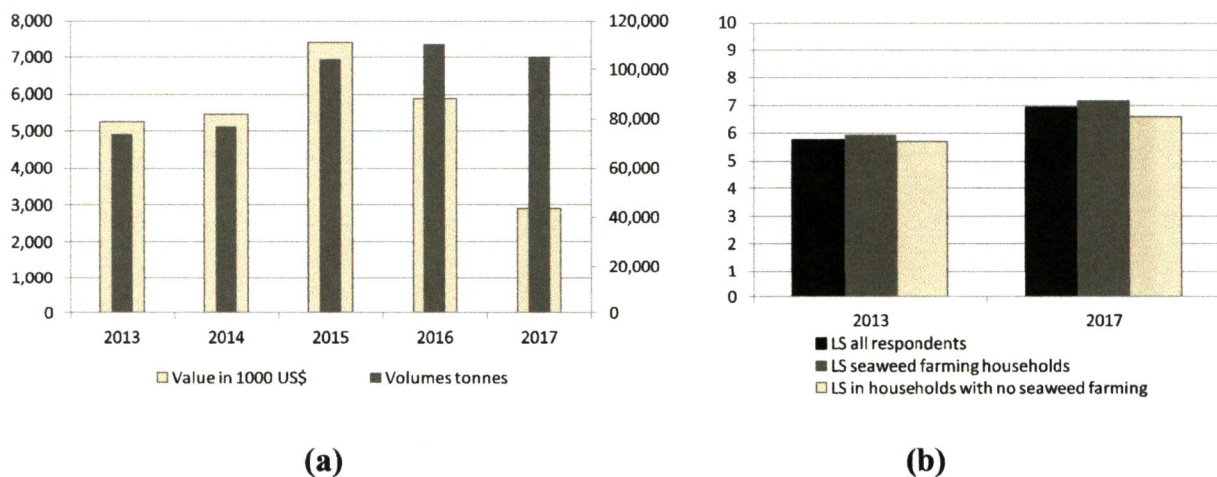


Fig. 2. (a) Seaweed production in Takalar Regency in USD ($\times 1000$) (left axis) and tonnes (right axis), for the period of 2013–2017; (b) life satisfaction (LS) scores for all respondents; women from the seaweed farming households ($n = 40$); and the households not engaged in farming ($n = 29$), for 2013 and 2017.

Table 2

Ten most important well-being factors reported by respondents. Imputed overall importance, change of satisfaction and W-IE scores. Well-being factors in **bold** are those reported as directly and positively impacted by seaweed farming.

#	Well-being factor	% (a)	Imp (b)	Overall Imp (c) = (a.b)	Sat now (d)	Sat before (e)	Sat Change (f) = (d-e)	W-IE (c.f)
3	Transport	46	8.76	4.02	7.91	4.73	3.18	12.80
2	Housing	49	8.13	3.96	7.41	4.50	2.91	11.51
10	Health	58	8.99	5.22	8.05	5.95	2.10	10.97
20	Environment	35	9.15	3.21	7.00	4.11	2.89	9.29
16	Basic needs	35	9.08	3.19	7.84	4.96	2.88	9.19
17	Secondary needs	38	8.93	3.38	7.46	4.78	2.68	9.06
11	Hajj	34	8.84	2.99	6.92	3.92	3.00	8.96
5	University	31	8.65	2.69	6.96	3.65	3.31	8.90
1	Clinics	31	8.13	2.53	7.78	4.43	3.35	8.47
18	Own businesses	35	8.65	3.04	6.78	4.00	2.78	8.45

Where,

% = percentage of respondents selecting this factor as important.

Imp = mean importance score.

Overall Imp = imputed, mean importance score multiplied by the % of respondents selecting the factor.

Sat now = mean score for satisfaction now.

Sat before = mean score for satisfaction 5 years ago.

Sat change = imputed, change in satisfaction score, satisfaction before deducted from sat now.

W-IE = imputed, well-being impact evaluation score, which is overall importance multiplied by change in satisfaction.

In addition to completing W-IE calculations, we looked for statistically significant differences in answers to each well-being question given by the women from seaweed farming families and those women who came from the non-seaweed farming families. We analysed data using the non-parametric Mann-Whitney *U* test in IBM SPSS v24 and found no significant differences in responses, indicating that the results can be reported as one cohort.

3. Results

3.1. The volume and value of seaweed farmed and self-reported assessments of satisfaction with life overall

Production in Takalar Regency increased from 74,000 to 105,000 t for the period of 2013 to 2017 (Fig. 2a). However, after a revenue peak of US\$7.5 million in 2015, the price per metric tonne steadily decreased. Despite increased production, the revenue in 2017 was under US\$3 million (in 2019 USD equivalent). Anecdotally, the decrease in revenue was associated with a shift from culturing *Kappaphycus* to the more robust, faster-growing but lower-priced *Eucheuma*. However, official data sources from Indonesia do not disaggregate Eucheumatoid production and consequently it is not possible to compare production and value of these two seaweeds over time. Overall life satisfaction (LS) reported by participants for 2017 (mean = 6.92 with SD 1.225; median 7) was significantly higher ($p < .001$) than for 2013 (mean = 5.76 with SD 1.403; median 6), (Fig. 2b). Satisfaction in 2013 was similar for both groups: women from seaweed farming households ($n = 40$) reported mean satisfaction of 5.93 (SD 1.309; median 6) similar to women from non farming households (5.69, SD 1.538; median 6; $n = 29$). In 2017, both cohorts reported increases in life satisfaction, with women from seaweed farming households reporting a 1.35 point or 23% increase to a mean of 7.18 and women from non-farming families reporting a 0.9 point or 15.5% increase to a mean of 6.59 (Fig. 2b). An increase in income was reported by 40% of respondents as the key reason for improved life satisfaction; while 32% attributed improvements to various government programs and improved infrastructure (hospital, roads etc).

3.2. Well-being contributors – Importance, satisfaction and perceptions of change

Well-being contributors, as perceived by the respondents, were obtained without any reference by enumerators to seaweed farming, that is, without any prompting. At least one respondent identified each

of 21 factors proposed (0) as being most important, which confirms that our compilation of factors did not include any irrelevant items. Importantly, no factor received a negative average satisfaction score change, and there were no reported negative comments related to seaweed.

Focussing on a subset of factors – the 10 which were selected by the largest percentage of respondents as being ‘most important’ – allowed us to calculate the W-IE score (Table 2). The first column provides the factor number and name; the second column (a) reports the percentage of respondents selecting that factor, while the third column (b) gives the average ‘importance score’ assigned to it by respondents. Multiplying (a) by (b) gives us an estimate of the overall importance of a factor to the sampled group, showing that transport, housing and health are the three most important contributors to personal well-being overall. Columns (d) and (e) report satisfaction with each factor now, and 5 years previously – the key message being that satisfaction has increased for all factors (Table 2, Column f). The highest positive changes were associated with clinics and other healthcare facilities (3.35 point improvement compared to 5 years ago), improved ability to send children to university/higher education (3.31 point improvement), improved transport (ability to purchase motorcycle, 3.18 point improvement), and the ability to start saving for Hajj (3.00 point improvement). The W-IE (final column; Table 2) is calculated by multiplying the overall importance score (Column c) by the reported change in satisfaction (Column f). High scores are associated with factors that are important to a large percentage of respondents and which have, reportedly, undergone significant change (for better or worse) during the previous 5 years. This reveals that the 10 most important changes affecting well-being that have occurred in the last 5 years are, in order: improvements relating to transport, housing, health, the natural environment, satisfaction of basic needs and secondary needs, savings for Hajj, children's access to university, health clinics and owning a business. Five of those well-being factors were reported by respondents as directly and positively impacted by seaweed farming in the village: transport; housing; fulfilment of basic needs; secondary needs; and university education (indicated as bold font in 0). When further questioned.

about the change and its link to seaweed farming, 22% of respondents reported that seaweed farming income played an important role in that it facilitated purchase of a motorbike (“Can buy new motorbike from one good [seaweed] harvest”, respondent 49); 15% linked seaweed farming to housing improvements (“Good seaweed prices allowed me to repair my house”, respondent 16); 11% and 26% linked seaweed farming income to an ability to purchase basic and additional

items, respectively (“Now I can buy things I need”, responded 61); while 5% of respondents linked seaweed farming to ability to send children to university (“Profit was used to educate children”, respondent 2). Women from the households not directly involved in seaweed farming also reported perceived benefits. These were linked to the ability to engage in seaweed processing (making cakes, ice-cream, soap, etc. from seaweed), opportunity to participate as paid labour (seaweed farming has “Reduced unemployment, [there are] jobs in the village”, respondent 20), or indirect benefits of, as one shop owner reported, “more money in the village” (respondent 19).

Health and the natural environment were reported as very important to villagers, and were amongst the top 10 most important well-being factors (0). Over the last 5 years, satisfaction with health has increased by 2.10 points, and with the condition of the natural environment by 2.89 points, to the current satisfaction of 8.05 and 7.00 points, respectively. However, there was no perceived linkages reported between seaweed farming and health or the natural environment within the villages.

4. Discussion

The literature on seaweed farming in Indonesia generally assumes that the income generated by seaweed culture directly benefits the farmers' families. Malik et al. (2015), however, question the sustainability of this income. The question of income sustainability also arises from data presented in this paper, noting that the value of seaweed produced has been falling since 2015. Although data relating to seaweed production and financial revenue are not reported in a way that allows one to estimate the financial impact of seaweed farming on households, we have been able to use the information to draw useful insights. Firstly, that the volume of seaweed farmed has been increasing steadily since 2013. Secondly, that seaweed revenues drastically reduced in 2016 and 2017, compared to 2015 – evidently, the fall in international seaweed prices was so substantial that the larger production volumes were not able to maintain revenues (although farm-gate prices have since risen again to well over US\$1500/t in 2019, as reported on [Jasuda.net](#)). This decrease in revenue might also in part be associated with a shift from culturing *Kappaphycus* to the more robust and faster-growing but lower-priced *Eucheuma*. However, data that would allow comparison of production and value of these two seaweeds over time is not available. Thirdly, while we were not able to obtain reliable information on the cost of seaweed farming, unless average costs have fallen in line with prices, profits (revenue minus costs) must also have fallen over that period. Thus, it is likely that regional reductions in seaweed farming revenues have also manifested as reductions in income for farming families. An important consideration here is that different crops and products have significantly different values – for example, the price of dry *Kappaphycus* is generally about three times the price of dry *Eucheuma*. Hence, disaggregated collection of production data related to different species is recommended, as well as further research related to economic and gender impacts of different seaweed value chains. Given the differences in value between the two species, and the potential recent preference to focus on low value-high volume *Eucheuma*, such data disaggregation would be very beneficial in terms of policy implications and the future management of the industry.

Nevertheless, decrease in national and regional revenues from seaweed noted in 2013–17 data had no corresponding reduction in reported levels of satisfaction with life overall. All responding women in our study, both from households that farm seaweed and those that do not, reported overall life satisfaction now as significantly higher than 5 years ago. Further, life satisfaction score of 6.92 reported by our respondents is much higher than the average Indonesian score recorded that year of 5.26 points (Clifton, 2017). The increased life satisfaction of all responding women supports reports in the literature that seaweed farming has positively transformed the lives of many villagers in South Sulawesi and elsewhere in Indonesia (Steenbergen et al., 2017). As

increasing population density and fishing pressure created a need for alternative sources of income, seaweed farming provided an opportunity in remote areas where coastal communities face a reduced number of economic alternatives (Neish, 2013). The key advantages for proliferation of seaweed farming are likely to be low investment, relatively simple culture techniques, regular income and profitability (Putra et al., 2013). Blankenhorn (2007) found that seaweed farming contributed a very high percentage to average household income of participating households in South Sulawesi. Seaweed farming has also been reported as complementary and compatible with other village activities, such as fishing and farming land crops; as well as with the existing village norms, rules and structures (Neish, 2013). Pollnac et al. (2003), examining perceived changes in material lifestyles upon adoption of seaweed farming in North Sulawesi, found that 79% of their respondents that had recently adopted seaweed farming reported being better off than 5 years earlier; and 73% of those specifically said that they are better off because of seaweed farming. However, Crawford and Shalli (2007), in their study of two villages in Tanzania, found that seaweed farming did not improve overall household income compared to non-seaweed farmers, with seaweed farmers actually doing worse. Thus, a better understanding of the dynamics in Indonesia could potentially assist other emerging production countries to better harness their opportunities and potentially replicate Indonesia's ‘success story’.

We found that our respondents deemed transport (motorcycles), housing, health, natural environment, fulfilment of basic and secondary needs, ability to save for Hajj, sending children to university, (health) clinics, and owning a business, as factors of the highest importance to their well-being, and they reported increased satisfaction with those factors. Five of the ten most important well-being factors were not perceived by respondents as linked to seaweed farming. Perceived improvements in factors such as health and natural environment were rather linked to general regional development and improved awareness. The other five factors were reported by respondents, without any prompting, to have changed for the better because of the seaweed farming. Purchasing a motorbike, improving the condition of the house, fulfilling basic and other needs, ability to send children to university, were perceived by respondents as stemming from income that is related to the seaweed farming. The well-being factors selected by our respondents as the most important, such as health, housing, children's education, environment, are very much in line with the reports from elsewhere (UN, 2007) and are similar to those of Valderrama et al. (2013), who reported that many seaweed farmers have experienced substantial improvements in their standards of living. Increased incomes were also reported as resulting in improved housing and education in different development and geographic contexts (Adams Jr. and Cuenca, 2010). To the best of our knowledge this study of individual well-being and household benefits of seaweed farming is the first application of W-IE method in aquaculture. The W-IE method was well accepted by both participants and Indonesian university researchers who were trained in the method. It generated comprehensive results and has potential to be developed as a standard method for similar explorations in other seaweed farming, and more general aquaculture, regions of the world.

The natural environment was, overall, the fourth most important well-being factor. The condition of natural environment was perceived as having improved over the last five years, and this was mainly due to perceived improvements in rubbish management and control. Like health, respondents did not make any direct associations between environmental quality and seaweed farming. This is despite research suggesting that there is a link, for instance, if construction of seaweed farms impact on seagrass habitat (Eklöf et al., 2006). However, Blankenhorn (2007), also working in Takalar district, concluded that the current culture methods of seaweed farming in the region do not interfere with the seagrass flora and that reduction of habitat quality for the associated fauna is minimal. For some other forms of seaweed farming the damage has already been done, for example many of the

coastal ponds now used for *Gracilaria* culture were constructed for shrimp or milkfish culture with considerable loss of mangrove habitat in Takalar district, although the rate of mangrove loss to aquaculture ponds has slowed greatly in recent years (Malik et al., 2015). Furthermore, seaweed farming can even have positive environmental impacts, since it is often associated with reductions in some types of fishing (Blankenhorn, 2007; Crawford and Shalli, 2007; Hill et al., 2012; Sievanen et al., 2005) and research has found a positive correlation between seaweed farming and populations of rabbitfish (Family Siganidae) in Indonesia (Hehre and Meeuwig, 2016). It is likely that generalisations relating to the environmental impacts of seaweed farming, positive or negative, are fraught and a more nuanced understanding of the ecosystem and its recent history is required to make such judgements.

The main potential negative personal and social effects of seaweed farming reported in literature are health impacts. Fatigue, musculoskeletal pain, hunger, respiratory problems, eye related problems, injuries from hazardous animals and sharp shells in the water and allergies, were the most serious health issues reported by seaweed farmers in Zanzibar (Fröcklin, 2012), and the FAO (2017) study found that women engaged in seaweed farming reported declining health, including the lack of sleep due to extra effort. In contrast, in our study, reference to health was uni-directional: good health was perceived as pre-requisite for farming; but seaweed farming was not seen as impacting health in either a positive or negative way. In addition, women participating in our study reported no negative impacts of additional income, although negative side-effects of increasing household incomes have been reported elsewhere in the literature as spending on social ills (alcohol, drugs, prostitution, etc.) and increase in family violence (Saxena et al., 2003). It is common for women in South Sulawesi to have a strong financial position within the household and even to be the main income earner. Although such a situation can potentially lead to marital tensions, previous studies on the impacts of seaweed farming indicate that such marital problems were few (Neish, 2009). Our study also found no evidence of marital discontent as a result of financial distributions.

In Indonesia, seaweed farming is particularly well suited for smallholder farmers: it uses little capital, requires only simple farming techniques and has short production cycles (Neish, 2013). The observed growth in the industry has not been imposed 'top down' by large corporations, government or development agencies, but has instead occurred through seaweed farmer groups operating under their own initiative: farms were built in response to strong market 'pull' from carrageenan and agar manufacturers who sought the cultivated raw seaweed sources essential to supplement limited wild-harvest sources (Neish, 2013). In this region, seaweed farming operates as community-level farming, where additional labour is sourced from non-farming families in the village and non-farming villagers also benefit from the spending of additional funds (in local shops and services), from seaweed processing and transport to the markets. Both men and women are engaged in the industry. Although their roles are sometimes partitioned, from our observations, the payment for labour appears to be equal. There is thus evidence that seaweed farming does not only benefit farming families; indirect benefits are felt throughout the community (Putra et al., 2013). This observation is supported by our research, which also uncovered no evidence at all of perceptions of rising inequality within the villages who participated in this study. There was no statistically significant difference between life satisfaction scores of women from seaweed farming households and those who do not have seaweed farms. It appears that the community 'spillovers' play an important role. We therefore recommend that future research takes more of a value chain approach to exploring the impacts of the seaweed industry beyond the farming; considering other related activities such as seaweed trading, processing, and transportation. Our results from Indonesia that capture perceptions of community benefits are markedly different to seaweed farming elsewhere in China, Korea and even the

Philippines, where farm ownership can be by large corporations or outsiders, with locals providing poorly paid agricultural labour only (Hurtado et al., 2015). Further, seaweed farming has rapidly become integrated into the social fabric of South Sulawesi villages to the point where it is now regarded as a 'traditional' economic activity (Neish, 2013). The importance of institutional arrangements supporting small-scale family operations (Neish, 2009), local decision making rights and capacity (Steenbergen et al., 2017) and social sustainability (Rebours et al., 2014), is thus significant.

5. Conclusions

Data relating to seaweed production and financial revenue are currently not reported in a way that allows one to estimate the financial or other impacts of seaweed farming on households. The novel W-IE approach used in this study allowed us to learn more about the causal mechanisms of how seaweed farming has improved well-being of women from participating coastal communities in Indonesia. Not all of the improvements in the lives of respondents were due to seaweed farming, however, we were able to find positive economic and social impacts of seaweed industry on participants. Five of the ten most important contributors to participants' well-being were reported as directly and positively impacted by seaweed farming: transport; housing; fulfilment of basic needs; secondary needs; and university education. Reports of increased life satisfaction throughout villages, both by women from families engaged in seaweed farming and those who are not, suggests that growth of the industry may have occurred without creating 'winners' and 'losers'; evidently the benefits are perceived to be spread reasonably equitably through the entire community.

Seaweed farming in South Sulawesi is a dynamic industry, with distinct price volatility and reasonably fluid changes between farmed species because of similar equipment requirements. There appears to be a trend in farmers shifting away from *Kappaphycus* toward mariculture of the lower priced *Eucheuma* and marine *Gracilaria*. Implications of such trends on the villagers wellbeing, and vice-versa, are worth further exploration.

Perceived benefits of seaweed farming in South Sulawesi might be due to historic development of the industry in Indonesia where it has been dominated by smallholders and supported by engaged traders. In this region, the industry has very much grown from the 'bottom up' without external 'pushes'. More recently, the Government of Indonesia has set production 'targets' that could be regarded as an emerging 'push'. Our research suggests that attempts to further increase the production through large-scale commercial aquaculture ventures that could support more value added processing in country, should ideally be designed in a way that builds upon the successes identified here – ensuring there are ample opportunities for entire communities to become involved with, and benefit.

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Human ethics

The University of Sunshine Coast Human Ethics Committee approval.
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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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